THE ACTION OF STRONG CURRENTS OF ELECTRICITY UPON NERVE CELLS.

PIERRE A. FISH, D. Sc., Washington, D. C.

(PRELIMINARY NOTE.)

The researches of Hodge, Mann and Vejas have demonstrated that weak electric currents sufficiently prolonged, have been able to produce unmistakable changes in the structure of the nerve cell, as an evidence of fatigue. Such changes have been found in the cells of the cerebrum as well as in the spinal and sympathetic ganglia.

If instead of a weak and prolonged current a much stronger and shorter current be applied, ought more emphasized symptoms of fatigue to be expected?

If fatigue be continuous, with no opportunity for recuperation, death would ultimately ensue. Since a weak current applied directly to the nerves causes exhaustion, it would seem reasonable to infer that a very strong current applied to the skin at the proper places would tire a person to death very quickly, and, at least, leave as marked changes in the nerve cells as the weak current does.

This question was of paramount interest, when, in April, 1894, there came into my possession while at Cornell University, Ithaca, N. Y., a portion of the cervical myel of L. R. W., a victim of an electrocution.

Such statements as the following might lead one to expect some very radical change in the appearance of the cells: "1,740 volts were sent coursing through the body, pounding at his nerve centers with all the force of so many trip-hammers," and again, "the current shattered his nerve cells."

In the case of L. R. W. portions of the cervical myel were cut in two planes, transverse and sagittal. The cells in the ventral horns were examined particularly and the conditions

found in Figs. 3 and 4 were noted. Vacuoles varying in size and number were located throughout the cell-body, intruding more or less upon the area of the nucleus. This intrusion appeared to me not as a direct invasion within the nuclear area, but as an overlapping of the nucleus by the vacuoles. In many cases the margin of the vacuole abutted against that of the nucleus, and occasionally there appeared to be a slight indentation in the latter at this point The nucleolus was well marked.

If judgment were to be passed after the examination of the material from this individual only, it would perhaps be most natural to conclude that the vacuolation of the nerve cells was due to the action of the electricity.

It was not generally believed that the murderer was insane, nor that he was an excessively heavy drinker of alcoholic spirits, either of which, as well as other diseases, are said to cause vacuolation in the nerve cell.

In April, 1895, I was enabled, personally, to procure some more material. The tissues were in the fixing reagents within four hours after the electrocution. They were selected from the same regions as in the former case and some of them hardened and examined by the same methods for exact comparison.

In this individual the nerve cells showed the normal conditions so far as the microscope could reveal them. Very rarely, indeed, there could be detected a slight suggestion of a vacuole in a cell.

The murder committed by this man was of the most wanton and brutal character, and it was believed by some that he was insane. He brooded over the conditions of his birth, (he was an illegitimate child) his anxiety to know of his parents, coupled with the shame they had bestowed upon him, worried him greatly and may have affected his mental balance.

The appearance of the nerve cells, however, did not indicate this so much as in the first case, where no special claim of insanity was made. The gross aspect of the brain presented nothing uncommon, except that its weight was a little more than the average.

Age conditions need not enter, for both were young men, the

former, L. R. W., being about thirty-five and the latter, W. L., about twenty-four years old.

The evidence based upon these two cases is conflicting and unsatisfactory; but when compared with the results of others from similar material, the condition found in the second case (W. L.) seem to correspond, namely: that no apparent abnormal phenomena are shown. This also holds true for other than human tissue, for in the brain of a calf experimentally electrocuted and examined histologically, Dr. Wm. C. Krauss, of Buffalo, N. Y., in 1890, found "the result of the microscopic examination negative as far as the physical condition of the separate brain elements are concerned."

The question as to the instantaneity of death is still a matter of controversy and does not properly come within the scope of this paper.

The rapidity of the electric current depends upon conductivity, amount of potential, as well as other things.

It is certain that a nerve is not nearly as good a conductor as a copper wire, nor is it said to be as good as the blood.

Even if the nerve be a relatively poor conductor of electricity, the estimated rate of passage of the current, as compared with that of a nerve impulse, would leave the balance considerably in favor of the electricity, making it probable that the current arrives at, and paralyzes or kills the nerve cells before the sensation can be conveyed there.

Experiments performed upon dogs, by those interested in the subject, show that the heart is the first of the vital organs to cease its visible action. This has been observed by first anæsthetizing the animal, removing a sufficient portion of the parietes, keeping up respiration by artificial means and then applying the current; instantly the heart was seen to stop its beating. The effect was just as marked when the experiment had been carried so far as to cut the vagus nerves. In the majority of cases the heart was still before the respiration had stopped.

Of twenty-four dogs tested in this respect there were only three in which this was a matter of doubt, and in these three "no priority could be assigned to the failure of either function."

Dr. A. M. Bleile (Electrical World, N. Y., July 6, 1895) believes that death from electric shock is due to the contraction of the arteries, caused by the action of the current on the vasomotor center, and that this constriction of the arteries offers a mechanical impediment to the flow of the blood which the heart is not able to overcome. When nitro-glycerine or nitrite of amyl was given to counteract this effect, greater currents of electricity could be borne.

The question arises, if the use of these reagents, after the electrocution, would not relieve this constricted condition, or, as has been suggested by others, that an application of a medical electric current might bring about the same result and promote resuscitation.

Amperage must be taken into account as well as the voltage. A continuous current of very high voltage may be received without fatal results. A very rapid, alternating current, in which the alternation is so rapid as to be practically continuous, likewise is not necessarily fatal.

The current usually employed at electrocutions, 1,700 volts and eight amperes, is said to be equal to about twenty horsepower. Such a force turned loose into a human body must effect wonderful changes in the living tissue, although for the most part subtle enough to evade detection by the microscope. The constituents of living protoplasm are too little known to enable us to understand what changes are effected or just how they are brought about. It is not probable that one tissue or system of tissues is selected by the electricity as it traverses the body, although there may be different degrees of susceptibility. Death may be brought about by the killing of the cells in the nerve centers. The electricity in this case acting as a fixing agent, for as in histology, when certain reagents or in some cases simply their vapors are allowed to act on living nervous tissue, it not only kills, but fixes or retains the elements of the tissue in the position they held at the time of the action of the reagent.

This reaction is of a chemical nature ; it probably is in the case of electricity. When properly employed the reagents cause no

visible change in the form of the tissue elements, neither apparently does the electric current.

Whether this hypothesis of electric fixation is applicable to all tissues of the body, it is now too early to say, thus far it seems to be a rational one.

Such lesions as have been noted seem to be of a secondary character, such as minute effusions in the heart caused by capillary rupture due to too violent contraction; the crenated appearance of the red blood corpuscles taken from the body in the region of contact of the electrodes some seven minutes after the execution, as described by Dr. Fell.* While corpuscles taken one-half hour after the execution from a region farther removed from the electrodes presented no abnormal appearance as to size or uniformity of outline.

* Proceed. Amer. Soc. Microscopists, Vol. XII., pp. 1-34, 1891.

EXPLANATION OF PLATE.

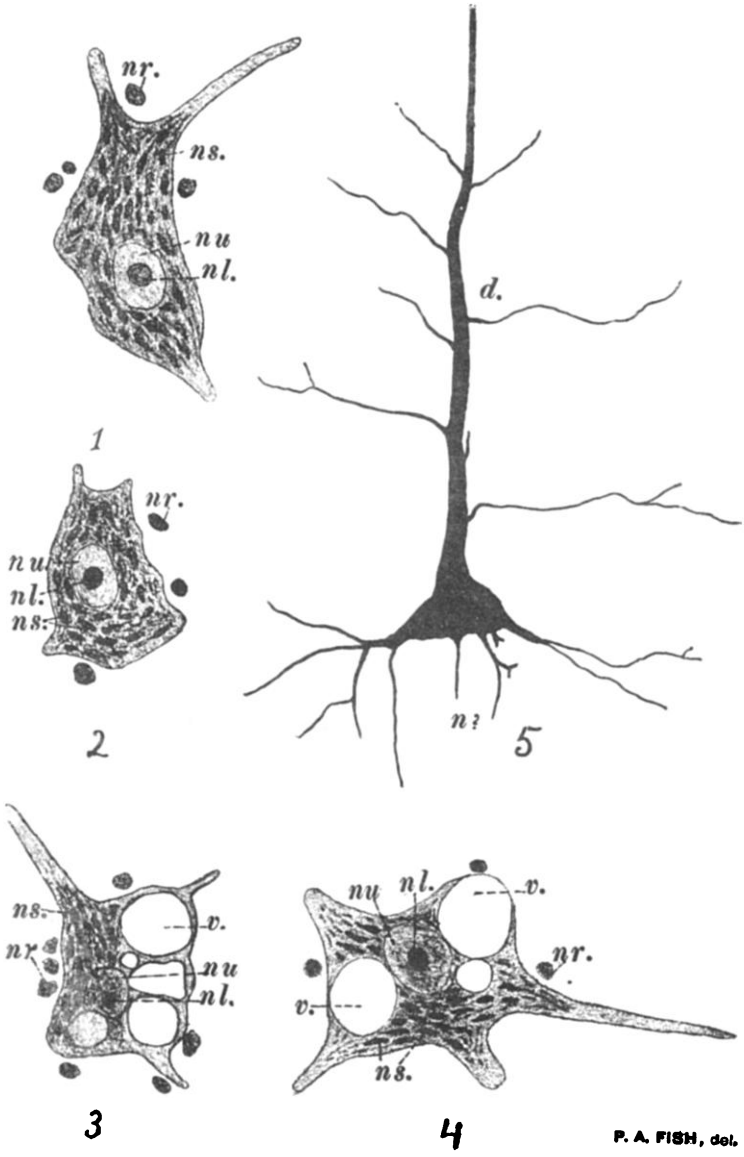
d =dendrites.
n ?=neurite.
nl =nucleolus.
nr=neuroglia or spider cells.
ns=Nissl's spindles.
nu=nucleus.
v =vacuole.

Figs. 1 and 2 From cervical myel of case No. 2 (W. L.) Sagittal plane.
Figs. 3 and 4. From cervical myel of case No. 1 (L. R. W.) Sagittal plane.

The methods used in the preparations from which Figs. 1–4 were taken, were not adapted to bringing out the appendages of the cell to any great extent. Such parts of the cell processes as are shown are undoubtedly dendritic, the neurite not appearing.

Fig. 5. Pyramidal cell from the cortex of the precentral gyre. Case No. 2 (W. L.) Formalin-bichromate-silver preparation.

PLATE.



P. A. FISH, del.